Exhibit B

Walking Speed and Stride Length Predicts 36 Months Dependency, Mortality, and Institutionalization in Chinese Aged 70 And Older

Jeanne Woo, Suzanne C. Ho,† and Ashley L. M. Yu‡*

BACKGROUND: Increasing emphasis is being placed on physical performance measures as an outcome predictor. It is uncertain whether one or two simple measurements will have predictive value compared with a battery of tests.

OBJECTIVES: To assess whether simple performance measures such as walking speed and stride length will predict dependency, mortality, and institutionalization.

DESIGN: A 3-year longitudinal study of a random sample of subjects.

SETTING: Older people living in the community in Hong Kong, Special Administrative Region, China.

SUBJECTS: A total of 2032 Chinese subjects aged 70 years and older were recruited territory-wide by proportional random sampling and followed for 3 years.

MEASUREMENTS: Functional status was measured using the Barthel Index at baseline and follow-up. The time taken to walk a distance of 16 feet and the number of steps taken were measured at baseline. Stride length is estimated by dividing 16 by the average number of steps needed to complete the walk. Outcomes regarding dependency, mortality, and institutionalization at 36 months were recorded.

RESULTS: After excluding subjects lost to follow-up and those who had died, data were available for 559 men and 612 women. Univariate analysis showed that reduced walking speed and stride length were associated with increased risk of dependency, mortality, and institutionalization. In multivariate analysis for dependency and mortality, stride length, walking speed, age, and sex were included in the best prediction model (ROC = 0.798 and 0.707, respectively), whereas only stride length was included in the prediction for institutionalization (ROC = 0.764).

CONCLUSIONS: In terms of prevention or modifying outcomes, these two simple performance measures may be used as indicators for checking for occult disease and for interventional measures such as exercise prescription. J Am Geriatr Soc 47:1257–1260, 1999.

From the *Department of Medicine and Therapeutics, †Community and Family Medicine, and the ‡Centre for Clinical Trials and Epidemiology, The Chinese University of Hong Kong, Shatin, Hong Kong.

Address correspondence and reprint requests to J. Woo, Dept. of Medicine and Therapeutics, Prince of Wales Hospital, Shatin, N.T., Hong Kong.

Key words: walking speed; stride; dependency; mortality; institutionalization

It has been observed that walking speed and length of stride are reduced among older people,[1,2] and both disease-related factors and age-related physiological changes contribute to this decline.[3] Walking speed provides an objective measure of performance in physical function together with other performance measures.[4] Such measures are useful for comparison of function in cross-sectional or longitudinal studies and have been related to health outcomes. It has been shown that a physical performance battery assessing lower extremity function is useful in predicting outcomes, providing information not available from self-report evaluation.[5] Objective measures of lower extremity function among non-disabled older persons were highly predictive of subsequent disability.[6] It is uncertain whether a single measure of lower extremity function, such as walking speed, will be sufficient to predict health outcomes compared with a battery of performance measures. Since both age and disease contribute to dependency, mortality, and institutionalization, and both these factors affect walking speed and stride,[3] it is possible that measurement of walking speed will be useful in predicting these three outcomes. To address this question in a health survey of Hong Kong Chinese aged 70 years and older carried out in 1991, walking speed was examined and related to outcomes at 36 months.

SUBJECTS AND METHODS

In 1991–1992, a cohort of 2032 Hong Kong Chinese subjects aged 70 and older was recruited for a study to examine factors associated with healthy aging. The source used was the non-means-tested Old Age Allowance Scheme, which covers more than 90% of the Hong Kong older population, together with the registrants of the Disability Allowance list. A stratified disproportional random sampling was used, with 300 subjects for each of four strata: men aged 70 to 79 and 80 + years and women aged 70 to 79 and 80+ years; 150 subjects were used for each of six strata: men aged 80 to 84, 85 to 89, and 90+ years and women aged 80 to 84, 85 to 89, and 90+ years. The overall response rate was 60%.

0002-8614/99/$3.50

Details of the sampling method and of the baseline cohort have been reported elsewhere.[7–10]

Interviews were conducted at the subjects' place of residence and consisted of a questionnaire together with physical measurements. The questionnaire covered socioeconomic, physical and psychological health, and functional status.[7–10] The presence or absence of disease was based on self-report of doctor's diagnosis together with a check of drugs taken. Functional status was measured using the Barthel Index,[11] a brief measure of activities of daily living (maximum value = 20). The interviewer also asked each subject who was able to do so to walk a distance of 16 feet, recording the time and the number of steps taken. An average of two readings was taken. A larger number of steps taken to complete the distance implies a smaller stride length. Stride length is estimated by dividing 16 by the average number of steps to complete the walk. Subjects were contacted at 18 months when telephone numbers and addresses were updated and were reinterviewed at 36 months using the same questionnaire. Death was documented by information from relatives or caregivers and also by a search at the Death Registry, which included subjects lost to follow-up because of death.

There were 999 men and 1033 women at baseline, among whom 932 men and 903 women were able to complete the 16-foot walk. After 36 months, excluding subjects lost to follow-up and those who had died (Table 1), 559 men and 612 women remained for reinterview. The outcomes in terms of dependency (measured as the Barthel index at 36 months), mortality, and institutionalization (for subjects who were living in the community originally at baseline) were examined in relation to the baseline walking speed and the stride length.

Statistical Analysis

Logistic regression analysis was used to assess the effects of stride length and walking speed at baseline on mortality, dependency, and institutionalization at 36 months. "Best" model was determined by comparing the area under the receiver operating characteristic (ROC) curves.[12]

RESULTS

Walking speed, stride length as estimated by the number of steps taken, and outcome indicators at 36 months, by gender, are shown in Table 2. Women had slower walking speed and took a larger number of steps to complete the 16 ft walk. They also had higher dependency and a greater number of falls and incidence of institutionalization at 36 months compared with men. In univariate analysis, both walking speed and number of steps taken are significantly associated with 36 months outcomes (Table 3). A longer time taken and a smaller stride length are associated with increased risk of dependency, mortality, and institutionalization. Table 4 shows the best models using stride, walking speed, age, and sex to predict 3-year outcomes using ROC curves. Adjusting the stride length for height did not improve the area under the curve. For dependency and mortality, stride length, walking speed, age, and sex are included in the best prediction model, whereas only stride length is included in the prediction for institutionalization.

DISCUSSION

With populations aging worldwide, increased attention is being paid to the burden of disease and disability,[13] indicators of this burden, and preventive methods to prolong

Table 1. Number of Subjects in the Study

	Male			Female		
	70–79 Years	80+ Years	Total	70–79 Years	80+ Years	Total
No. of subjects at baseline	596	403	999	576	457	1033
No. able to complete 16-ft. walk (%)	580 (97.3%)	352 (87.3%)	932 (93.6%)	545 (94.6%)	358 (78.3%)	903 (87.4%)
At 36 months						
Alive	399 (67.0%)	160 (39.7%)	559 (56.0%)	379 (65.8%)	233 (51.0%)	612 (59.3%)
No. lost to follow-up	95 (15.9%)	73 (18.1%)	168 (16.8%)	115 (20.0%)	59 (12.9%)	174 (16.8%)
No. died	102 (17.1%)	170 (42.2%)	272 (27.2%)	82 (14.2%)	165 (36.1%)	247 (23.9%)

Table 2. Baseline Walking Speed, Stride Length, and Outcome Indicators at 36 Months by Gender

	Male (n = 559)	Female (n = 612)
	Mean (SD)	Mean (SD)
Baseline walking speed (sec)	10.59 (4.89)†	13.85 (9.56)
Baseline stride length (ft)	1.32 (0.34)†	1.09 (0.31)
	No. (%)	*No. (%)*
36-month dependency (Barthel Index < 20)	119 (21.3%)**	208 (34.1%)
36-month institutionalized	16 (3.1%)*	29 (6.5%)
36-month falls	136 (24.3%)*	188 (30.8%)

MVF, chi-square test: * $P < .02$; ** $P < .001$.
t test on log transformed data: † $P < .001$.

Table 3. Univariate Analysis of Walking Speed, Number of Steps on 3-Year Outcome Measurements, Adjusting for Age

	Dependency		Mortality		Institutionalization	
	OR (95% CI)	*P* Value	OR (95% CI)	*P* Value	OR (95% CI)	*P* Value
Male						
Walking speed	1.190 (1.13–1.26)	<.001	1.080 (1.05–1.11)	<.001	1.087 (0.99–1.19)	.066
Stride length	0.082 (0.04–0.18)	<.001	0.238 (0.14–0.40)	<.001	0.094 (0.01–0.62)	.014
Female						
Walking speed	1.163 (1.12–1.21)	<.001	1.035 (1.02–1.05)	<.001	1.031 (1.00–1.06)	.038
Stride length	0.021 (0.01–0.05)	<.001	0.230 (0.13–0.42)	<.001	0.096 (0.02–0.42)	.002

Table 4. Prediction of Three-Year Outcomes by Walking Speed and Number of Steps

	Variable	OR (95% CI)	*P* Value
Dependency	Age group (80+)	2.199 (1.34–3.60)	.002
	Sex (female)	1.310 (0.86–1.99)	.207
	Age groups·Sex	0.426 (0.23–0.80)	.009
	Speed	1.094 (1.05–1.14)	<.001
	Stride length	0.153 (0.07–0.33)	<.001
	ROC = 0.798		
Mortality	Age group (80+)	2.152 (1.66–2.78)	<.001
	Sex (female)	0.505 (0.39–0.65)	<.001
	Speed	1.023 (1.01–1.04)	.006
	Stride length	0.353 (0.22–0.57)	<.001
	ROC = 0.7065		
Institutionalization	Age group (80+)	1.796 (0.88–3.68)	.110
	Sex (female)	1.364 (0.67–2.77)	.391
	Stride length	0.095 (0.03–0.30)	<.001
	ROC = 0.764		

active life expectancy. In recent years, performance-based measures have been used as indicators to assess mobility.[4,14] These measures are carried out easily by nonmedical personnel, and there is no need for equipment. Of these measures, the timed walk is a simple and well tested method that correlates well with other methods of measuring gait speed and with exercise capacity, falls, joint deformity, lower limb power, balance, and general health, as well as with height. It has good interrater reliability and intraclass correlation coefficient for repeated tests. Both mobility measures and subjective measures of health have been shown to be predictive of mortality.[15] Simple physical performance measures were strongly associated with instrumental activities of daily living independence[16] and with future healthcare utilization and health status.[17] However, performance-based measures have not been found to be superior to self-rated measures.[18] A practice effect for performance measures has also been observed, which may render these indicators less sensitive to change.[19]

In this survey, only one performance measure (timed walk) was used because of time constraint at the interviews. Features of this measure alone (speed and stride length) were able to predict 36-month outcomes. This is important for future health surveys because the test is easy to do and can be incorporated as an outcome indicator, and a whole battery of tests may not be necessary. Walking speed and stride length are known to be correlated with height,[20] and, therefore, height was initially included in the ROC analysis. However, for the best-fitting curves, it was not included as a predictor variable for mortality.

The explanation for the association between walking speed and stride length and outcome is unclear. We have established previously that both age and underlying disease may account for age-related changes in gait. Both age and presence of disease will affect the three outcome measures documented in this survey. Such diseases may include all the neurological diseases affecting gait – commonly cerebrovascular or Parkinsons's disease, joint diseases, or diseases affecting cardiorespiratory function-limiting exercise tolerance. In the absence of diseases, it has been postulated that the age-related reduction in speed may be the result of defective striatal dopaminergic mechanisms[21] and decline in calf strength.[20] In a study by Guralnik et al.,[6] only subjects who were nondisabled initially were included; yet objective measures of lower extremity function were still highly predictive of subsequent disability. It is likely that decline in function may occur as an age related change or may represent occult disease. In terms of prevention or modifying outcomes, the usefulness of this simple measure would be as an indicator for checking for occult disease and for interventional methods such as exercise prescription.

REFERENCES

1. Elble RJ, Sienko-Thomas S, Higgins C, Colliver J. Stride-dependent changes in gait of older people. J Neurol 1991;238:1–5.

2. Elble RJ, Hughes L, Higgins C. The syndrome of senile gait. J Neurol 1992; 239:71–75.
3. Woo J, Ho SC, Lau J et al. Age-associated gait changes in the elderly: Pathological or physiological? Neuroepidemiology 1995;14:65–71.
4. Guralnik JM, Branch LG, Cummings SR, Curb JD. Physical performance measures in aging research. J Gerontol 1989;44:M141–146.
5. Guralnik JM, Simonsick EM, Ferrucci L et al. A short physical performance battery assessing lower extremity function: Association with self-reported disability and prediction of mortality and nursing home admission. J Gerontol 1994;49:M85–94.
6. Guralnik JM, Ferrucci L, Simonsick EM et al. Lower-extremity function in persons over the age of 70 years as a predictor of subsequent disability. N Engl J Med 1995;332:556–561.
7. Ho SC, Woo J, Lau J et al. Life satisfaction and associated factors in older Hong Kong Chinese. J Am Geriatr Soc 1995;43:252–255.
8. Woo J, Ho SC, Lau S et al. Prevalence of cognitive impairment and associated factors among elderly Hong Kong Chinese age 70 years and over. Neuroepidemiology 1994;13:50–58.
9. Woo J, Ho SC, Yuen YK et al. An estimation of the functional disability burden in elderly Chinese age 70 years and over. Disabil Rehabil 1996;18:609–612.
10. Ho SC, Woo J, Chan SG et al. Risk factors for falls in the Chinese elderly population. J Gerontol 1996;5:M195–198.
11. Mahoney FI, Barthel DW. Functional evaluation: The Barthel Index: A reliability study. Md State Med J 1965;14:16–25.
12. Hanley JA, McNeil BJ. A method of comparing the areas under receiver operating characteristic curves derived from the same cases. Radiology 1983; 148:839–843.
13. Murray CJL, Lopez AD. The Global Burden of Disease. Geneva: World Health Organization, 1996.
14. MacKnight C, Rockwood K. Assessing mobility in elderly people. A review of performance-based measures of balance, gait and mobility for bed side use. Rev Clin Gerontol 1995;5:464–486.
15. Parker MG, Thorslund M, Nordstoom ML. Predictors of mortality for the oldest old–A 4 year follow-up of community-based elderly in Sweden. Arch Gerontol Geriatr 1992;14:227–237.
16. Myers AM, Holliday PJ, Harvey KA, Hutchinson KS. Functional measures: Are they superior to self-assessments? J Gerontol 1993;48:M196–206.
17. Judge JO, Schechtman K, Cress E. The relationship between physical performance measures and independence in instrumental activities of daily living. The FICSIT Group. Frailty and Injury: Cooperative Studies of Intervention Trials. J Am Geriatr Soc 1996;44:1332–1341.
18. Studenski S, Wallace D, Guralnik J et al. Gait speed as a clinical vital sign. J Am Geriatr Soc 1998;46:S59.
19. Tager IB, Swanson A, Satariano WA. Reliability of physical performance and self-reported functional measures in an older population. J Gerontol 1998;53:M295–300.
20. Bendall MJ, Bassey EJ, Pearson MB. Factors affecting walking speed of elderly people. Age Ageing 1989;18:327–332.
21. Barbeau A. Ageing and the extrapyramidal system. J Am Geriatr Soc 1973; 21:1145–1149.

ERRATUM

In the July 1999 *Journal* Table of Contents, the editorial Function, Flying, and the Age-60 Rule was incorrectly attributed. The correct name of the author is Germaine Odenheimer. The *Journal* regrets the error.